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OMICS based Interventions for Climate Proof Crops

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Abstract Agriculture – the key to human civilization without doubt can be regarded as an essential part of our daily lives providing us our bread and butter. Food production or creation of fibers, fuels, raw materials & biopharmaceuticals forming the fundamental basis of human and animal sustenance is because of crop and other plant species. With a long history of humankind and agriculture co-existence, and immense & indispensable importance of agriculture in human sustenance today, it is therefore our duty to further promote and sustain agriculture. The present global scenario takes our attention to what we call 'Climate Change'. Adverse change in climate can lead to imbalance in food production and ultimately imbalance of the human health, nutrition, and happiness. It is evident that the impact of climate change covers all regions. Thus, we need strategies that enable us to increase our food production to feed the ever-growing human population and at the same time keep sustainability and effect on environment in mind. This is where the term sustainable agriculture comes into play. Indefinite food production without causing severe or irreversible damage to the ecosystem is the key. Sustainable agriculture should not be misunderstood by totally abolishing new technologies. But it actually aims at developing technologies that helps in improving agriculture production without having negative impact on the environment. We here propose certain biotechnology-based strategies that can overcome negative impact of climate change and will also lead in improving future food production and livelihood. Droughts, irregular precipitations, deviated temperatures are predicted to be frequent in the near future. The question is, how do we tackle these problems? There is a need to have climate proof crops, i.e. the crops that can sustain various abiotic stresses. So far conventional means have been exploited but looking at the looming population and the intensity of climatic vagaries the need is to focus on new technologies having solutions with sustainability. One such technology is omics, and where transcriptomics and proteomics are two key approaches. Large numbers of genes/proteins that are involved in regulating different stresses and finally can be exploited to generate next-generation crops to enable enhanced food production are available. Molecular breeding has tremendous scope that will ensure introgression of desirable traits in cultivars without any linkage drag. Biotechnology also provides us the platform to look for desirable genes across genera and even the kingdom. Thus genome revolution has to play a role in next green revolution to have climate proof crops that can improve future food production and livelihood for sustainable human habitations.

Keywords Climate proof crops; Abiotic stress; Genomics; Proteomics

Background

The imprints of climate change are clear. Numerous crises and devastations due to this environmental change are evident. There is a lot of discussion about the means to cope with such changes. The report of Declaration of the World Summit on Food Security (Document WSFS 2009/2; Rome, 16-18 November 2009) states that more than one billion people worldwide are hungry and poor, and this number, it further states, will increase if governments do not spend more on agriculture (Source-UN Food and Agriculture Organization). So the need is to increase world agriculture output by 70% between 2011 and 2050 to feed a world population that has recently crossed 7 billion in October 2011 and further exceeding to 9 billion by 2050. There are a lot of deviations due to present climatic changes that lead to decrease in timely precipitation, increase in temperature, and have drastic effect on sustainability. The threat for resources like water, food, health, land and environment are evident. Agriculture will be affected largely by such changing climate and the need will be to have next generation crops that will be climate proof. A decline in the crop yield will also impact all other aspects of life. The changing climate will affect various plant processes such as germination, flowering, time of pollination, fertilization, seed development etc. The final outcome will be the reduction in the yield of crops. Many threatened species are needed to be conserved and biotechnological tools can play a crucial role. Hence, one of the major tasks is to increase the crop production under such devastating conditions viz-a-viz conservation of biodiversity to attain sustainability and feed the growing population. For increasing crop production, we cannot ignore the dependence on technologies, a technology having prolific outcome with sustainability is a ray of hope for betterment of agriculture.

1 Impact of climate change

As discussed, climate change will lead to deviation in precipitation, temperature, etc and which will have an impact on crops. About 50% of available irrigation water is required for rice cultivation in India (Kumar, 2006), and as per predictions there will be frequent droughts in future so the need is to develop varieties that can grow in low moisture content. As far as the impact of climate change on plant disease is concern, various published reports suggest that, due to altered temperature and precipitation profiles, new combinations of pests and diseases may emerge. Any increase in the frequency or severity of extreme weather events, including droughts, heat waves, windstorms or floods, could also disrupt the predator-prey relationships that normally keep pest populations in check. So the effect of climate may increase pest population that may be one of the reasons for loss of biodiversity (McMichael et al., 2003), and further it is believed that negative effects of climate change on agriculture in poor countries could put an additional 40 to 300 million people at risk of hunger by 2060 (McMichael et al., 2003). So we must plan for developing new varieties that can sustain very well under deviated climatic conditions.

2 Need for 2nd green revolution (GENOME REVOLUTION)

Dr. Borlaug an American agronomist is well known as the father of the Green Revolution (Brown, 1970; Borlaug, 2007). The technologies such as pesticides, irrigation, nitrogen fertilizers and development of improved crop varieties through conventional breeding methods were spread in the Green Revolution (Borlaug and Dowswell, 2004) that allowed food production to keep pace with worldwide population growth. The question is how to go further? As population is increasing at an alarming rate and conditions for agriculture are getting difficult due to changing climate. Hence, the need is to develop environmental friendly technologies that can improve agriculture and feed the growing population. One way is to adopt environmental friendly technologies for developing climate proof crops without ruining biodiversity, because it is the rich biodiversity that may provide useful genetic resources to withstand such potentially damaging (to crops) conditions. This is what we feel should be the next Green Revolution, which is possible by manipulating crop genomes. During Green Revolution, various conventional breeding approaches were applied, and that by now are fully exploited for enhancing the crop productivity. Now we need to work for genome manipulation (genes, proteins and metabolites) to further improve crop plants, and thus agriculture itself. Here we propose some OMICS based strategies for genome revolution.

3 Biotechnological approaches for next generation crops (climate proof crops)

3.1 Molecular breeding approach

Through molecular breeding, it is feasible to transfer traits in elite cultivars of a particular species. As number of QTLs for various abiotic stress tolerance related traits [e.g: long root in rice, Si accumulation in rice (Zargar et al., 2011)] have been mapped on different chromosomes, it is easy to introgress such QTLs giving tolerance against various abiotic stresses into desirable varieties. The strategy shown in the Figure 1 can be used to transfer the desirable markers. Through molecular breeding approach it is quite possible to go for background selection for rapid introgression of desirable markers without any linkage drag. This is the marker assisted back crossing procedure, represented in Figure 1. For background selection markers are be selected randomly from the genetic map of that species covering all chromosomes. It will be desirable to select the markers in such a way that whole chromosome is covered (equal distributed markers). Such marker should show polymorphism among the parents. The time limit can further be decreased by developing F1 population of contrasting parents (isogenic lines) and generating dihaploid (DH) population from pollen culture to get the homozygosity in an earlier generation and then analyzing the population for presence of desirable genomic fragments. Figure 2 represents the procedure of marker assisted selection with dihaploidy for introgression of desirable markers/ gene(s). Using DH population, the number of generations is tremendously reduced and utilizing the gene linked markers will assure the transfer of trait.

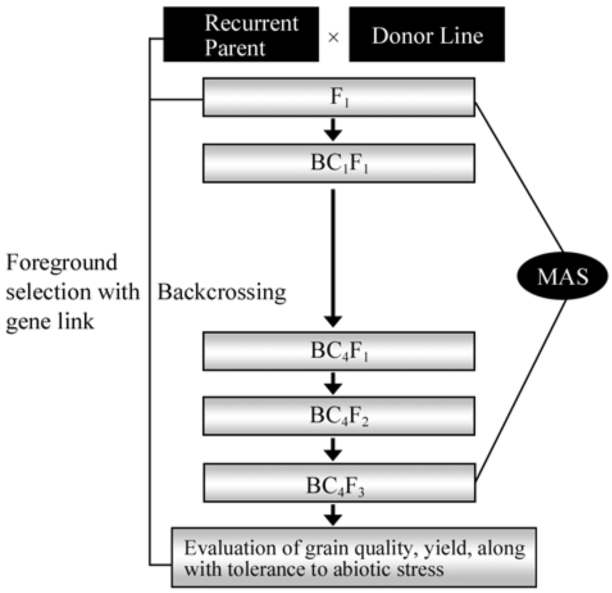

Figure 1 Marker assisted backcrossing for introgression of desirable markers (QTLs) in an elite cultivar

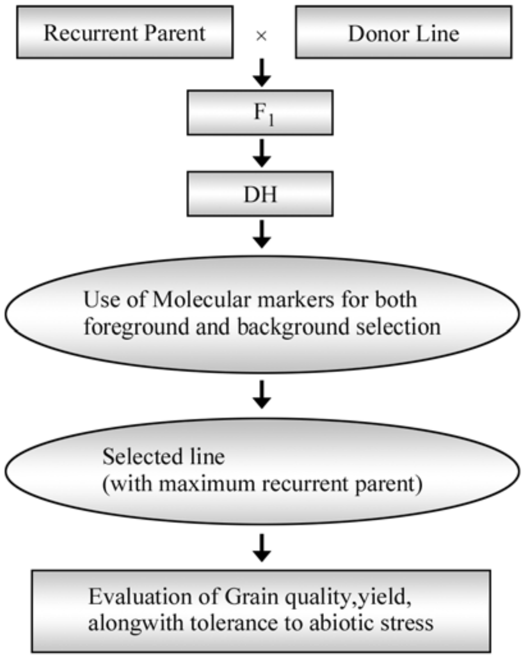

Figure 2 Marker assisted selection with dihaploidy for introgression of desirable markers (QTLs)

3.2 Proteomics based strategy to identify novel proteins induced due to some abiotic stress

By this approach, it will be possible to resolve and identify all the proteins that get differentially regulated by inducing a particular stress. 2-DGE (two-dimensional gel electrophoresis) is the best and easiest way to identify the differentially expressed proteins, by comparing the 2D gel profiles of proteins extracted from plant samples grown in different conditions. Once we have these profiles, we can locate the proteins whose expression is enhanced as well as reduced due to induction of stress. By means of MS (Mass spectrometry) these proteins can be identified and their functionality can be determined using various bioinformatics tools and such proteins can be assigned to various metabolic pathways. As such it will help us in understanding the actual impact of a particular stress on various metabolic pathways which may unlock the secret of potential versatility of different proteins. The strategy is explained in Figure 3.

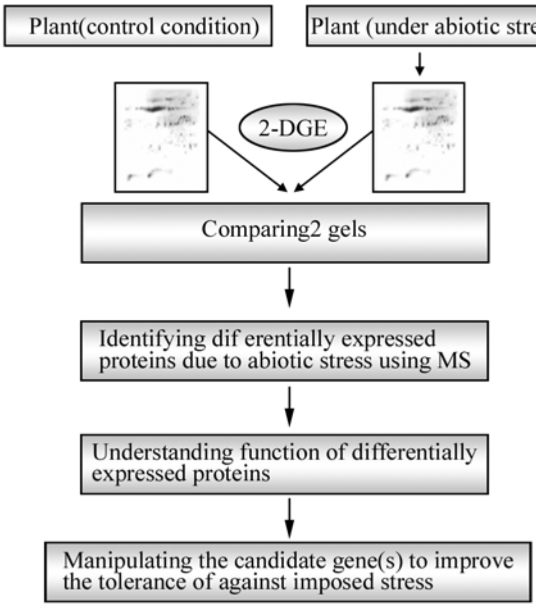

Figure 3 Proteomics based approach for identifying novel proteins giving tolerance against stress

3.3 Combination of various high throughput approaches to conserve plant diversity

The richness of biological diversity in India is evident; it is mainly due to varied climatic, altitudinal and ecological habitats. We have mountains that fall in tropical to temperate regions, and hence the number of plant species is enormous. There have been increasing rates of threats of depletion to these biological resources due to immense biotic and abiotic stresses. A total of 560 plant species of India have been included in the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened species, out of which 247 species are in the threatened category (Kapai et al., 2010). The changing climatic conditions may play a crucial role in depletion of this biological diversity. Various groups across the country are involved in identifying threatened species, conservation and analysis of their metabolic profiles and identification of a number of useful bio-molecules from these species has also been done. However, there is still a great potential within these species yet to be explored. These species can serve as a rich source of germplasm for identification of novel genes, proteins and metabolites. Various high throughput techniques like genomics, transcriptomics, proteomics and metabolomics can help us in the accomplishment of this goal. It is very important to conserve the threatened plant species. Conservation is possible by both in-situ and ex-situ methods (Figure 4). In-situ methods have been followed to conserve the biological diversity by defining biosphere reserves and protected areas. Although protecting plant or animal species in their natural habitats is the best method of conservation, but managing these protected areas becomes a major concern. Lax vigilance and poaching always causes biological damage.

Ex-situ conservation has its origin in setting up botanical gardens and zoological parks. Globally, ex situ conservation now plays a significant role in biodiversity conservation. Seed banks/gene banks, tissue culture, captive breeding, aquaria, forest nurseries have recently been added to ex situ conservation networks and have proven to be much useful, quick and effective. As such biotechnology provides us solution to conserve these threatened species. The need is to develop gene banks and various other efficient in-vitro systems to avoid loss of these important bio-resources.

Author Contributions

SMZ and MN wrote the paper, GKA and RR also read the manuscript and revised it. All authors had read and consented the final text.

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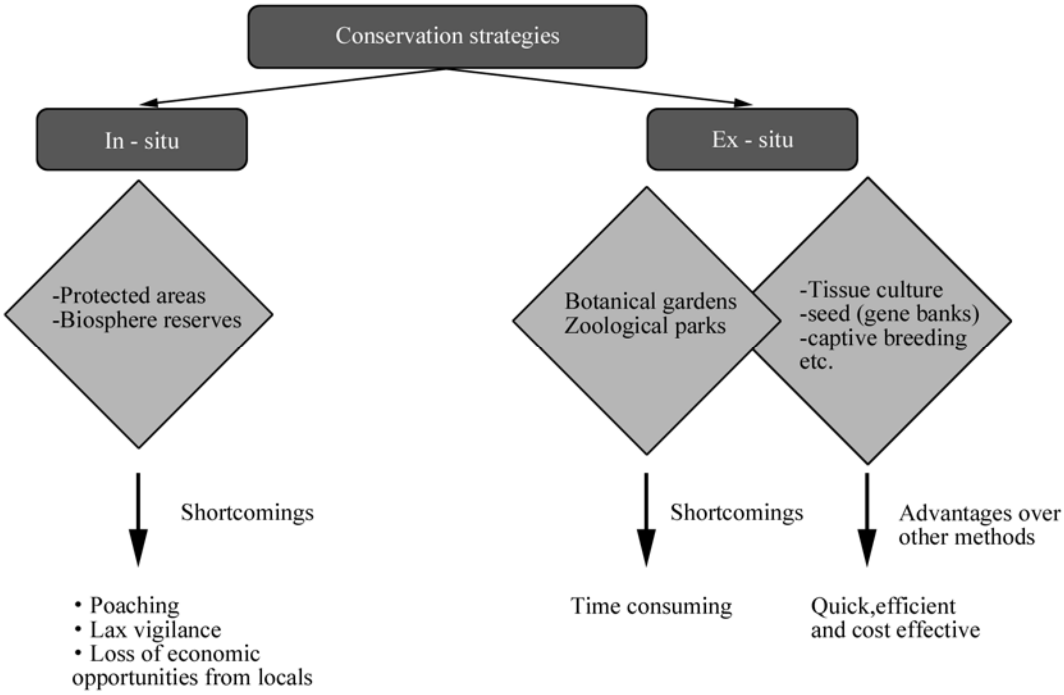

Figure 4 Techniques used for conservation of plant diversity

References

Borlaug N.E., 2007, Sixty-two years of fighting hunger: personal recollections, Euphytica, 157(3): 287-297 http://dx.doi.org/10.1007/s1-0681-007-9480-9

Borlaug N.E., and Dowswell C.R., 2004, Prospects for world agriculture in the twenty-first century, In La R., Hobbs P.R., Uphoff N., and Hansen D.O., eds., Sustainable agriculture and the international rice-wheat system, Madison: Marcel Dekker Inc., pp.1-18 http://dx.doi.org/10.12-01/9780203026472.ch1

Brown L.R., 1970, Nobel Peace Prize: developer of high-yield wheat receives award, (Norman Ernest Borlaug), Science, 170(3957): 518-519 http://dx.doi.-org/10.1126/science.170.3957.518 PMid:4918766

Kapai V.Y., Kapoor P., and Rao I.U., 2010, In Vitro propagation for conservation of rare and threatened plants of India – A Review, International Journal of Biological Technology, 1(2): 1-14

Kumar S., 2006, Climate change and crop breeding objectives in the twenty first century, Current Sci., 90(8): 1053-1054

McMichael A.J., Campbell-Lendrum D.H., Corvalan C.F., Ebi K.L., Githeko A.K., Scheraga J.D., and Woodward A., 2003, Climate change and human health: risks and responses, Chapter 6, Geneva: World Health Organization, pp.103-127

Zargar S.M., Nazir M., Agarwal G.K, and Rakwal R., 2011, OMICS based strategies for efficient accumulation of silicon in rice to enhance its tolerance against environmental stresses, Molecular Plant Breeding (online), 2: 98-100